

Affordances of PDAs: Undergraduate Student Perceptions

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Abstract

This paper reports on an empirical study of undergraduate student s' exploration and use of PDAs for educational purposes over a period of six months. In previous studies, educational applications of PDAs have focused mainly on exploring designed research or experiments, in which students have used this technology for prescribed learning tasks. Students have fewer opportunities to explore how PDAs can be used effectively for general educational and study purposes. How students perceive and use PDAs on their own is not well understood. This study explores student understandings and use of PDAs to support their academic studies at a university. It investigates students' free exploration and use of PDAs for various educational purposes through applying rich, descriptive qualitative research methodology. Two cases are reported in this study. Data collection methods included: interviews with students, a review of student artifacts created using the PDA, student electronic journals and observation of student PDA uses. Seven emerging categories of PDA affordances were identified. They include: *multimedia collection*, *multimedia access*, *communication*, *scheduling*, *data processing*, *connectivity* and *representation*. Each category is presented both at rich descriptive and interpretive levels. Implications regarding findings are explored.

Introduction

In recent years, Personal Digital Assistants (PDAs) have been increasingly designed, developed, and adopted in education (Roschelle, Sharples, & Chan, 2005). PDAs have been used as a technology tool for encouraging classroom collaborative learning (Zurita & Nussbaum, 2007), supporting experiential learning in the field (Lai, Yang, Chen, Ho, & Chan, 2007), supporting lifelong learning (Sharples, 2000), enhancing interactivity both in/out of class via a messaging system (Markett, Arnedillo Sanchez, Weber, & Tangney, 2006), helping improve administrative work via a handheld testing system (Segall, Doolen, & Porter, 2005), creating a powerful and engaging learning experience for young learners through game-based learning (Facer et al., 2004), enhancing face-to-face group interactions (Liu & Kao, 2007), scaffolding learners in context-aware learning (Chen, Chang, & Wang, 2008; Uden, 2007), and empowering learning outdoors, indoors, or in mixed environments (Robinson & Dodd, 2006; Schwabe & Goth, 2005; Swan, van 't Hooft, Kratcoski, & Unger, 2005). A majority of these applications have been carried out in the context of empirical studies, in which students have used handheld devices for pre-defined tasks. This research explores how students perceive and use affordances of PDAs on their own in varied settings for their academic studies at a university. Many learning technology innovations are often designed to exploit the capabilities of the technology itself rather than to meet learners' needs (Margaryan & Littlejohn, in press). There is, therefore, an emerging need to explore affordances of PDAs as perceived by students themselves. This research will help teachers and researchers better understand student needs and preferences, which in turn, will help improve mobile technology pedagogical practices in higher education.

In the sections that follow, we review the literature of educational affordances of PDAs, introduce the research methods, present and discuss the research results, and draw conclusions.

Affordances of PDAs for Learning

To describe functional and meaningful properties of the environment, Gibson (1977) coined the term “affordance”. Affordance refers to “what it [the environment] offers the animal, what it provides or furnishes, either for good or ill” (Gibson, 1977, p. 127). This concept emphasizes possible actions that the observer perceives as feasible in the environment (Gaver, 1996), and is interpreted as the properties of the environment that offer “the possibilities for action” (e.g., Young, 2004, p. 171). Further, Jonassen, Hernandez-Serrano and Choi (2000) posit that if learning technologies are tools for mediating the practice of learning, “the affordances of any [learning] technology are the properties of that environment that enable the effectiveness of the technology, the abilities of the learner to take learning actions” (p.113). Affordances are concerned with both the capabilities of the technology and the abilities of the learner to take learning actions effectively using the technology in certain environments. Affordances of the PDA therefore in this paper are defined as ‘*properties of the environment that offer the learner possible uses of the PDA for learning.*’

Affordances have been explored not only in the human-computer design process (e.g., Kafai & Ching, 2001), but also in the area of information communication technology (ICT) applications in education to investigate the possibilities that computer technologies provide for students in ICT-based learning environments (e.g., Klopfer, Yoon, & Perry, 2005; Laurillard, Stratfold, Luckin, Plowman, & Taylor, 2000). PDAs, like other ICTs, can also provide many affordances in mobile learning environments. Klopfer, Squire, and Jenkins (2002) describe five properties of handheld devices that produce unique educational affordances: (a) *portability* (can take the device anywhere); (b) *social interactivity* (can exchange data and collaborate with others); (c) *context sensitivity* (can gather data ‘just-in-time and place’); (d) *connectivity* (can connect handheld devices to other devices to create a shared environment), and (e) *individuality* (can provide scaffolding for individual paths of investigation). Churchill and Churchill (in press) carried out an empirical study on examining educational affordances of PDAs from classroom practitioner’s efforts, and found five educational affordances: PDAs as (a) a *multimedia-access tool* (e.g., access to e-books, web pages, presentations, interactive resources, audio files); (b) a *connectivity tool* (e.g., exchanging ideas and files, collaboratively building understanding); (c) a *capture tool* (e.g., capturing videos and still photographs); (d) a *representational tool* (e.g., creating representations that demonstrate student thinking); and (e) an *analytical tool* (e.g., using scientific and graphic calculators to aid students’ tasks). Liang et al. (2005) define educational communication affordance of handheld devices as consisting of two attributes: a communication mechanism and an educational application. These attributes include five affordances: posting, pushing, controlling, file-exchanging, and instant-messaging. The communication and portability affordances have also been identified in a ubiquitous mobile learning environment (Chen et al., 2008).

Patten, Arnedillo-Sanchez, and Tangey (2006), summarized handheld device functionality from a host of research studies, and developed a functional framework containing seven categories of handheld educational applications: (a) *administration* (e.g., calendars, contacts); (b) *referential* (e.g., dictionaries, translators and e-books); (c) *interactive* (e.g., drill and test); (d) *microworld* (e.g., constrained models of real world domains); (e) *data collection* (e.g., note-taking, data logging); (f) *location aware* (e.g., museum guides and augmented reality); and (g) *collaborative* (e.g., knowledge sharing). Patten et al.’s framework is further developed and revised by Clough, Jones, McAndrew, and Scanlon (in press) in their empirical study of adult workers’ informal mobile learning. Their main categories of applications are *referential*, *location aware*, *reflective*, *data collection*, *constructive* and *administrative*. The term ‘functionality’ of handheld devices in the frameworks is understood as educational affordances by Churchill and Churchill (in press). However, these are categories of handheld educational functionalities rather than ‘possibilities for action’ that reside in the relationship between users and handheld devices in certain environments.

As the affordances of handheld devices mentioned above are either obtained from varied designed experiments in which learners have used handheld devices for prescribed learning tasks, or from empirical study from the perspective of a practitioner, whether students themselves will be able to perceive and implement these properties of the technological environment is unknown. Therefore, this research study aims to investigate the affordances of the PDA that the students perceive and use for their

academic studies, and how these affordances support their academic studies.

Research Methods

Qualitative research through a multiple case study approach was adopted for a period of six months to gain a deeper understanding of student perceptions of the PDA in their academic studies at a university, and add confidence to the research findings (Merriam, 1998; Yin, 2003).

Student Profile

Five students were purposefully selected from first-year undergraduate students at a university and on a voluntary basis (Patton, 1990). We chose five students because we could only afford five PDAs for student free use in this research project. These five cases were investigated individually. Only two cases are reported in this paper as we intended to create thick description and interpretation of the cases. Three steps were involved in the student selection processes. First, 25 potential students were chosen out of a group of 69 students through an orientation seminar. A questionnaire was conducted in terms of student demographic information and their perceptions of computer technology use in relation to perceived usefulness and perceived ease of use. Second, focus group discussions were conducted to finalize the sample. Criteria were set up and coded for student selection based on the data collected through focus group discussions. The criteria for student selection were: positive attitude towards technology use (to expect that they could make more uses of the PDA); good self-management (to make sure that they could take good care of the device); staying in Hong Kong most of the time during the three-month summer vacation in the research year (for the convenience of data collection and to lessen chances for device damage or loss); different disciplinary studies (to examine whether student PDA uses varied from one disciplinary study to another, and what caused these differences); gender (to balance males and females); nationality/region (to examine whether students from different cultures used the device differently, and what caused these differences); and experience in using the PDA (to investigate whether experienced and inexperienced users varied greatly in terms of PDA uses). A consent letter containing terms and conditions for participating in this project was given to the students. The profiles of the two students reported on here (Sally and Andy) are presented in Table 1.

Table 1 Student profile

Student*	Age at the time of the study	Major	Sex	Year of study	Nationality at the time of the study
Sally	19	Journalism	F	1	Mainland Chinese
Andy	20	Engineering	M	1	Hong Kong (permanent resident)

**Pseudonyms are used to protect the students' identities.*

PDAs and Facilities

The handheld device adopted in this research was the wireless enabled Dopod 818 Pro with both phone and PDA functionalities (Figure 1). It supports 2 Gb mini or standard memory cards. In this project, each student was provided with one 1 Gb mini memory card for free use. The devices were distributed to students for six-months of free use. A package of mobile phone telecommunication services was granted to the students in order to encourage them to make good use of the devices. The students could access the Internet using the PDA on campus and in university dormitories. They could also use the PDA to get access to wireless Internet when they were at home as long as a broadband Internet connection was available.



Figure 1: Dopod 818 Pro

Research Questions

Two research questions guided the data collection and analysis of this study as follows:

1. What affordances of the PDA did the students perceive and use for their academic studies?
2. How did the affordances of the PDA support their academic studies?

Data Collection and Analysis

Simultaneous data collection and analysis lasted six months. To examine the research questions, three means of data collection were used: electronic student journals, student artifacts, and interviews. Content analysis was used to analyze the data at different stages. The study ensured validity through triangulation in terms of student e-journals, student artifacts, retrospective interviews based on the questions arising from the e-journals and artifacts, and in-depth individual interviews.

Student e-journals focused on students' reflections about their exploration and use of the PDA. A guide was provided for writing e-journals based on the focus of the study and to ensure that the students considered and wrote up comments relevant to the research project. These e-journals were intended to be used as 'introspective tools' in the research, giving the researchers access to "the students' voices" (Nunan, 1992, p. 118). Participants were asked to submit their reflective e-journals to an online learning management system once a week for a period of six months. After one month, a preliminary content analysis using participants' sentence descriptions as a unit of analysis was conducted to identify emerging affordances of the PDA by each participant. In the sixth month, another analysis was carried out to check whether previous perceived affordances of the PDA were continually used, and to trace other emerging affordances identified and reported by the participants.

Student artifacts in this research refer to screen captures or files that the participants made or carried out using the PDA. Collecting student artifacts was acknowledged as an unobtrusive method (Savenye & Robinson, 2004) for obtaining information about what the students do using the PDA. From the artifacts that participants submitted, the researchers were able to triangulate the perceived possible uses of the PDA they mentioned in their e-journals and interviews, and were able to trace changes of use by the participants over time (Hodder, 2000). Some handheld educational research studies have employed this technique as a data source collection strategy (e.g., Crowe & van't Hooft, 2006; Swan et al., 2005). Guidance with an example of the artifact was provided for the participants.

Two semi-structured individual interviews were conducted after the participants had used the PDA for one month and six months respectively. The interview questions were centered on: (1) what affordances of the PDA did participants perceive and use to support their academic studies? and (2) how did these affordances help them with their academic studies? The analysis of the interview data helped the researchers gain a better understanding about how affordances of the PDA were explored and used from the perspective of the participants. A list of affordances emerged from each participant. The researchers

took into account any one affordance that can be considered to “have both positive and negative connotations” (Conole & Dyke, 2004, p. 113). The students in this study also encountered a host of constraints in using PDAs, which will be presented together with the affordances.

Results

During the half-year use of the PDA, both Sally and Andy regularly submitted their e-journals and artifacts, came for interviews, and reported on their experiences and reflections.

The affordances of the PDA perceived by Sally in the first month were: *multimedia access*, *communication*, and *scheduling*. During the remaining five months of the project, Sally identified two new affordances: *data processing* and *multimedia collection*. In the meantime, she kept using the affordances identified previously. She considered that using the PDA for reviewing course-related material, referring to dictionaries and other downloaded multimedia, using the data processing tool to write up news reports, diaries, and assignments, and to manage her work and task schedules were the most important for her. The characteristics of *portability* and *ease of use* of the PDA use proved essential for her to take advantage of the PDA for her learning.

The affordances of the PDA perceived by Andy in the first month were: *multimedia access*, *scheduling*, *communication*, and *representation*. In the five months that followed he identified two extra affordances: *connectivity* and *multimedia collection*, and continued using the affordances previously identified. He considered that the most important potential use of the PDA were *multimedia collection* for recording tutorials and capturing lab results, *multimedia access* in terms of dictionary use, and *connectivity* of his PDA to printers and other PDAs. He also shared a similar view with Sally that the PDA's characteristics of portability and ease of use were critical factors for him to use the device for his learning.

The affordances, therefore, identified and used by the two participants in this research are: *multimedia access*, *multimedia collection*, *communication*, *scheduling*, *data processing*, *connectivity*, and *representation*. They are further illustrated as follows:

Multimedia Access

Possible uses of the PDA for accessing different on- and offline multimedia for learning support in terms of review and reference.

- Review: Multimedia access for reviewing course materials and examination papers, and listening to recorded lectures without time and place constraints.

Andy reported that he recorded lectures and tutorials whenever he considered them hard to digest in class. After class, he used the device to listen to the recorded lectures and tutorials so that he reflected on the lecture content. He mentioned that he reviewed a few lecture notes in PDF format. However, most of the lecture notes were in hardcopy only in his courses. These could not be downloaded and saved on the PDA. He found that PDF files were not easy to read due to the small screen size. He had to drag the mouse up and down and left and right while reading. Sometimes, one or two lecturers provided PowerPoint slides for them, but the file size was too big (e.g., over 10 megabytes). It was hard for him to use the device to open the files due to the limited computational power. In addition, some formulas in subjects such as Pure Math could not be shown properly on the device. Moreover, if the slides were very detailed, it was hard to read them due to the screen size of the PDA. He mentioned that he would make more use of the device to review lecture notes if softcopies of the notes with fewer-word descriptions and formulas were provided by the lecturers. In such cases, he could review course materials when convenient.

Sally, who studied journalism, reported that a great deal of the courses had reference materials and lecture notes for students to download and review before, during, and after lectures or tutorials. As some

of the course notes had many pages, Sally had no time to review them in hardcopy or on the desktop computer before the lectures. As soon as she joined this research project, she started to download and save the files on the PDA so she could review them during the class. She did not have to worry about forgetting to bring the hardcopy notes anymore. Sally also used the device to visit course blogs set up by the lecturer in Journalism (Figure 2). Sally found the PDA very helpful and convenient for her learning. However, Sally admitted that she preferred reading only outlines of the course materials on the small screen.

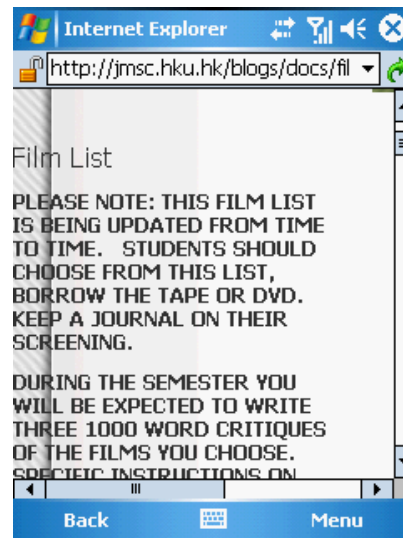


Figure 2: Screenshot of the Course Blog Film List

· Reference: Multimedia access for referring to e-books, on-and offline dictionaries, downloaded materials, or video clips for anywhere, anytime learning support.

Andy reported that it was the examination period when the research project started, so he often used the device to look up dictionaries, both on-and offline. He noted in his e-journal:

There are many technical terms in mechanical engineering that I do not understand. I downloaded a dictionary so that I could check the meaning of the terms whenever I wanted. If I wanted to know more detailed information of the term, I would access the Yahoo Online Dictionary. This helped me a lot in my study, especially during the examination period.

Andy also used the device to read downloaded e-books in English during breaks to improve his English (Figure 3), or refer to a map using the downloaded software MapKing to find out places in town (e.g., the place to buy the books recommended by a professor). However, the PDA did not support the MapKing 2005 version well and caused the system to hang. To fix the issue he downloaded the latest version (MapKing 2007). Andy also reported that he used the device to listen to recorded tutorials, but never used the device to watch videos, and rarely used it to listen to music because he considered the audio quality of the PDA not good enough.



Figure 3: A Sample e-Book

Andy also reported that the PDA's Internet access capability was very helpful for him in terms of checking course results on time, downloading past examination papers for immediate use, downloading pictures for reference in designing models during lab experiments, and searching call numbers of books in the university library online so that he could find out about books immediately without taking extra notes in class. However, Andy noted that only a few key websites like Yahoo, Google, BBC, and the university library had PDA versions. Besides, the PDA was an English version: browsing the website in Chinese slowed down the loading speed of the web pages. Andy mentioned that he could not use the device to visit online forums and WebCT. This prevented him from effectively searching information online using the device.

Sally mainly used the device to read downloaded e-books whenever she had time. At the very beginning of the study, she downloaded a whole e-book in one file. When she opened the file, it often resulted in freezing the device due to the large file size. Gradually she found that she could automatically save an e-book chapter by chapter. It was easy for her to open each chapter file and locate where she had been reading the previous time. She reported in an interview that she was exposed to varied writing styles through the e-books, which was beneficial for her writing skills. However, Sally felt disappointed that she could not download e-books from the university library to the PDA because of copyright protection measures on university resources.

Another important use of the device for Sally was the reference tool so she could practice her English and do exercises using on-and-offline English. She reported that when traveling with her family in Mainland China, she downloaded English exercises from 'New Concept English' (Figure 4). She was very happy that she could learn without taking a thick book while traveling. Checking the dictionary whenever she encountered new words in her reading was also very useful.

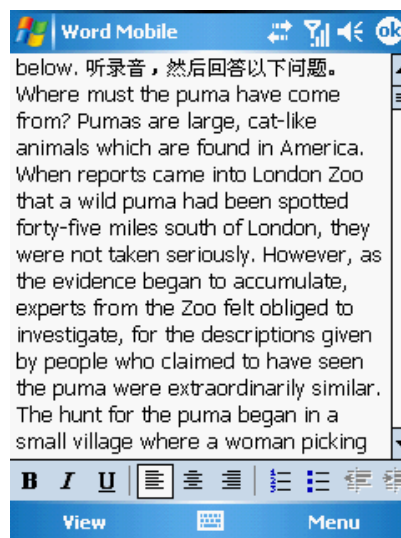


Figure 4: New Concept English Screenshot

Sally reported in her e-journal that in her residence hall (even when she was using her laptop to do some tasks) she would use of the PDA to look up new words, as it was more convenient and faster than using her computer. She explained in a retrospective interview:

If I use the computer to consult an online dictionary, I usually have to open another window to copy and paste the key words in the online dictionary. Because my laptop processing speed is slow, it will further slow down the response rate.

If she was on campus, Sally often connected the PDA to the Internet using WiFi to listen to some English programs online during breaks and read the BBC news (Figure 5) to improve her English. However, she found the problem with Internet access was that when she wanted to enter keywords to search a new website, she had to perform a soft reset on the device because the electronic keyboard would not pop up. This was inconvenient.

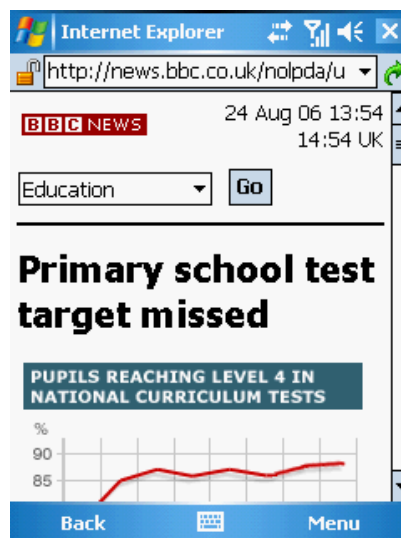


Figure 5: Screenshot of BBC News Report

In addition, with this device, she watched video clips that were useful for her course of study. Sally reported that one semester, she chose a course 'Special topics in journalism: Documentary'. She had to

watch different documentary films to compare and contrast their features for the assignment. She downloaded and saved some video films on the device, and watched them when she was commuting or taking a break. She reported in an interview:

I could make small chunks of time to watch the documentary films from time to time, and made reflections afterwards. This enhanced my understanding of the films, and also helped me do the assignment better.

However, she never learned to take videos using the device. She did not think it was a necessity for her to make such use of it.

With the help of CE-star Chinese software, Sally learned to write traditional characters, which were new to her as she had learned only simplified Chinese characters when she was in Mainland China. She found that the text input for Chinese was not stable, and the PDA could not show Chinese characters properly in PDF files due to the lack of supporting software.

Multimedia Collection

Possible uses of the PDA for collecting data such as audio, pictorial, and text data in varied contexts for learning support using the Camera, Notes, and Recording functions on the PDA.

Andy used the PDA and special recording software he downloaded to record tutorial lectures for review later on when he found that the tutorial was hard for him to digest in class but important for preparing for the final examination of the course. He said that the recording function was one of the most important uses for his learning. The original recording software on the device was not very effective, so he downloaded software for the PDA from the Internet. He also captured the lab results in experiments using the camera function. He noted in his e-journal:

In a lab experiment, we were asked to work in groups to make a product mold, and some finished products. In my group, after we finished the work, I used the camera to take pictures of the model and the final products, and then “infrared” them to my group members to share the experiment results and as a reference for writing the lab report later (Figures 6 and 7).



Figure 6: Screenshot of a Product Mold in a Lab



Figure 7: Screenshot of the Finished Product in the Lab

Such PDA uses provided possibilities for all group members to do comparisons and as a reference of the lab results, which was useful when they wrote up lab reports later. The PDA was also used to capture key slides in lectures, as these slides could not be accessed after class. Andy also mentioned that he did not often use the note-taking function of the PDA because the device did not properly recognize his writing. He did, however, note that the situation would improve if he spent more time learning how best to write with the device.

Sally used the camera function on the PDA to capture handouts, which saved her from the need to copy them line by line. She also took pictures of leaflets and banners at press conferences to help her recall these events when writing news reports (Figure 8). She mentioned in her e-journal that without the PDA, she could not collect as much useful information within the limited time available. Sally also collected data using the notes function. She noted down useful paragraphs for later writing while reading in the library, took minutes, or wrote memos in meetings. She noted in her e-journal:

With this device, I make a lot more notes than before... I now realized how much information I had previously missed before I started using this device.

Sally seldom used the device to record lectures for later review because the audio file size was too big.



Figure 8: Screenshot of the Press Conference

Communication

Possible uses of the PDA for communication via varied channels such as SMS, phone calls, emails, and MSN.

Andy mentioned that because he could check university web-mail, Gmail, and Yahoo mail using the wireless PDA on campus and at home, he gradually formed the habit of checking emails as soon as he got up in the morning, and throughout the day he checked the messages much more often (Figure 9). Checking messages via the PDA was much faster than using a computer. It just required pushing the button to turn it on and off. "There's no warm up time with PDAs," he said.



Figure 9: Screenshot of E-mail from Faculty

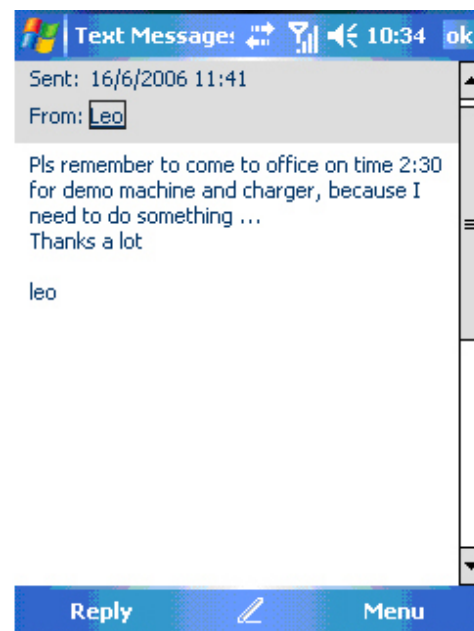


Figure 10: Screenshot of SMS to a Group Member

Andy mainly made use of SMS or MSN messaging when making phone calls was not convenient, informing his classmates and society members of key notices. But Andy said that SMS could only be used for communicating succinct messages, not for complicated problems which needed detailed explanations (Figure 10). Sometimes he asked his friends about simple learning problems he encountered in MSN chat. However, he mentioned that usually he could only chat with one friend. If he was chatting with several friends at the same time, it would force the PDA to hang up. Andy reported that he made more phone calls during the examination period to exchange course review information, ask questions, or answer questions to the related course. In most cases, the phone was used for chatting. Andy noted that the SMS messages from the university library informed him of deadlines for returning books and picking up the books (Figure 10). He found this function was very useful. He did not have to worry about overdue book returns and getting fined. He hoped that the university could provide more such services for students.

However, Andy reported that he barely used the device to communicate with the lecturers in the university. He noted in an interview:

I will not send SMS or make a phone call to the professors in my faculty... it is not polite to do so. I usually send emails to them if necessary. But I will not use the PDA to write emails to professors because there is no spelling and grammar check program in the device. I am afraid that it will be awkward if I make many grammatical and spelling errors in these emails.

Sally reported that at the very beginning of her PDA use, she explored the possibility of using the MSN messenger to chat with friends, and this she did. However, later she found that the MSN Messenger connection was not stable. Often the messaging was stopped before she completed the communication with friends. She made few uses of it later on. Even so, the PDA was great for checking emails from anywhere on campus (Figure 11). It was far more convenient and quick for her to check emails on her PDA than having to go to a computer lab. Though she sometimes wrote emails with a few lines to her friends using this device, she seldom wrote emails to her teachers because she was afraid of making mistakes. Sally also used the device to make phone calls to friends, mainly for chatting, but sometimes she would discuss problems with her friends, which could not be clearly and easily elaborated in emails. She mentioned that sometimes she preferred making phone calls to meeting her friends face-to-face as making phone calls made her feel more relaxed and at ease. Sally noted that she did not send messages via SMS very often in Hong Kong as the cost of making phone calls is very cheap compared to the cost in Mainland China.

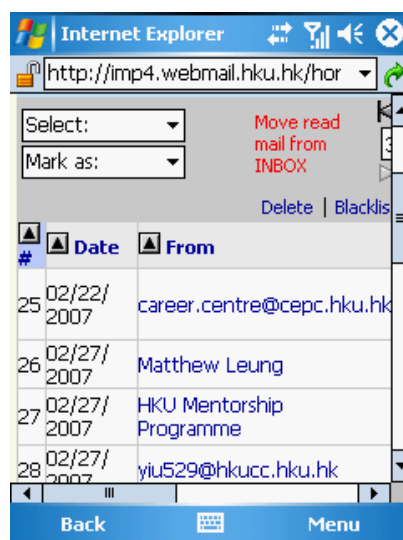


Figure 11: Screenshot of the Webmail Inbox

Scheduling

Possible uses of the PDA to manage schedules using Tasks or Calendar.

In the initial interview and in student e-journals and artifacts collected, it was noted that both students used the PDA to schedule regular activities and appointments using the Calendar function as soon as they started using the device. Sally reported her exploration and use of it in an interview:

When I first started using the PDA, I input the same activities taking place each week into the Calendar manually. No sooner did I realize that if it worked like this, the design was clumsy. It should have some better uses. So I tried each setting in the Calendar function and finally found how to set the reminder in the Calendar. I was so happy about this use.

In later interviews and e-journals, Sally and Andy mentioned that they usually checked their Calendars every day at the beginning of a semester, and gradually lessened the frequency of checking as they could remember most of the regular activities. In addition, they used Tasks for noting down activities or appointments that occurred irregularly. Sally said that she often set the deadlines a bit early so that she had time to make preparations to meet the deadlines. Andy mentioned that when comparing the Calendar to the Tasks, it was faster to find the tasks to be done due to the ease of navigation. They both synchronized the Tasks function with their laptops or desktops so that they could edit them conveniently.

Sally and Andy reported that the scheduling functions helped them manage their study-related activities, assignment deadlines, appointments and various student functions more efficiently. They became more punctual by doing so. On the other hand, it seemed that they were getting more and more dependent on the device, and tended 'to remember fewer things'.

Data Processing

Possible uses of the PDA for word processing documents such as news reports or diaries using Mobile Microsoft Word.

During her summer internship, Sally worked for China Central TV (CCTV) Hong Kong in a China project. She was involved in several interviews each day and wrote news reports afterwards. During this two-month summer internship, she found that the Mobile Microsoft Word on the PDA was one of the most important tools. She noted in an interview:

When we prepared a news report on the spot, both written language and pictures were used. While the other editors were doing the picture shooting and cutting, I could edit the news report using this PDA [Figure 12], and asked my teacher to comment on it immediately after I finished the writing. The PDA improved my efficiency in news reporting.



Figure 12: Screenshot of the Edited News Report

Sally also wrote diary entries using the Mobile Microsoft Word tool when convenient (e.g., when waiting for a bus, etc.). This was almost impossible without this device as she mentioned that she had no habit of writing diaries anywhere, anytime using paper and pen.

Connectivity

Possible uses of the PDA for file sharing and printing by connecting the PDA with other PDAs or printers.

Andy explored the possibility of connecting his device with a laser printer for printing his lab reports. He noted in his e-journal:

I had two months of training during summer internship to do experiments in the lab and write lab reports. Today, we were asked to submit a lab report, but the printer in the lab was out of order. I copied the file on the SD card and put it in my PDA because I did not bring my laptop. I found that there was a laser printer with an infrared function at my faculty. I tried to connect the device with the laser printer but encountered problems at the beginning. I did not give up and tried to sort the problems out. Finally, I solved the problem by using the PDF file instead of Word file as the PDA could not transmit a Word file to the laser printer. I was really excited by this 'discovery' and usage of the PDA.

Andy also exchanged files with other group members in a project by connecting his PDA with others' via Bluetooth in order to work collaboratively and communicate more efficiently for group projects, such as writing the lab reports mentioned in the section on multimedia collection. He found that exchanging files using Bluetooth was faster than using the Infrared function, especially when the file size was big. Andy noted that if there were more students in his class using similar devices, he would make better use of this connectivity capability. Only a few students had such devices, which limited the file sharing opportunities among them.

Representation

Possible uses of the PDA for representing complicated concepts in Notes or via graphic software.

Andy reported in his e-journal about using the PDA to help other students to solve problems by using the Notes function (Figure 13):

On one occasion, my classmate asked me about the microstructure of a metal. As I had no paper on hand at that moment, I used my PDA to draw the structure immediately to help him solve the problem.

Majoring in Mechanical Engineering, Andy had to learn triple integration of data relationships in Pure Math. As the triple integration of data relationships could hardly be presented merely via statistics without graphs, Andy downloaded specialized calculator software that helped visualize the graphic relationships by putting the statistics into the program (Figure 14). However, Andy found that the PDA was limited in computational power. Some software he downloaded to the device, such as Formula Editor, did not operate properly. However, Andy did not expect that the device could be as powerful as an ordinary computer. To him, the PDA remained an important supplementary device for supporting his academic studies.

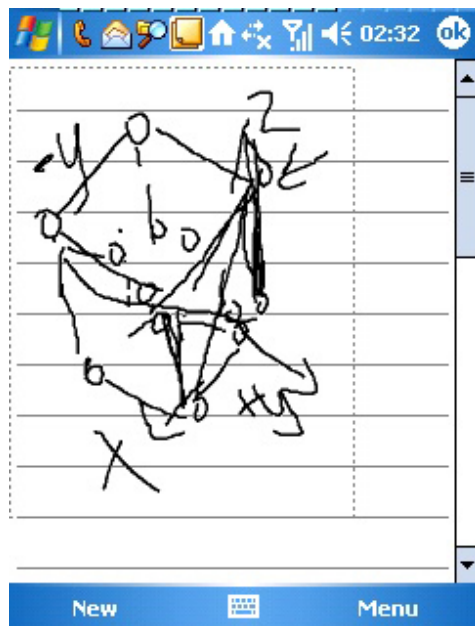


Figure 13: Screenshot of the Drawing of a Metal Microstructure

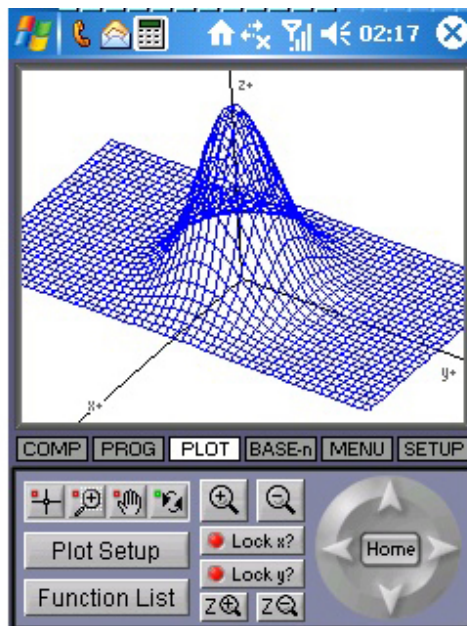


Figure 14: Screenshot of the Drawing of a Triple Integration

Discussion

Among the seven affordances found in this study, *multimedia access*, *connectivity* and *representation* affordances have been explored by a school practitioner in Churchill and Churchill's case study (in press), and the *communication* affordance of handheld devices has also been explored in a classroom environment via a designed communication system (Chen et al., 2008). Other research studies have investigated the functions of handheld devices in *managing tasks and activities*, *reference*, *data collection*, and *connectivity* (e.g., Chen & Kinshuk, 2005; Clough et al., in press; Colevins, Bond, & Clark, 2006; Corlett, Sharples, Bull, & Chan, 2005; Fallahkhair, Pemberton, & Griffiths, 2007; Liang et al., 2005; Markett et al., 2006; Naismith, 2007). However, the majority of these studies have investigated the functionalities of the handheld devices in designed learning environments where students used handheld devices for prescribed tasks. Though Churchill and Churchill's (in press) study did allow the user to explore PDA affordances, the study aimed at exploring the possible educational capabilities of the PDA from the perspective of a technician instead of the actual exploration and use of these capabilities for varied learning activities from the perspective of students as was done in this study.

The research results show that the PDA affordance of *multimedia access* was perceived to be one of the most useful and was one of the most frequently used affordances for the students' academic studies in terms of review and reference. The *multimedia access* affordance provided the opportunities for the

students to have “control over their own goals” (Jones & Issroff, 2007, p. 248), and define and perform their learning tasks whenever they needed (e.g., watching clips of videos for doing a course assignment). It also supported the students to do episodic learning activities in small chunks of time and at different locations (Song, in press). However, we have to be aware that some constraints were encountered in the course of students’ *multimedia access*. On the one hand, the constraints of the PDA technology such as the small screen size, the limited computational power, and the poor quality of audio functions restricted students’ use of the PDA for learning purposes (e.g., giving up reviewing the course material in PowerPoint file); on the other hand, the students appropriated some of these constraints for their uses in some situations. For example, e-books were downloaded chapter by chapter to counter the limited computational power of the PDA; only outlines of the course reading material were downloaded for review to cope with the small screen reading.

In addition, institutional and social factors also influenced the students’ use of the PDA. Though the university provided students’ free internet access on campus, and students could search the call number of library books via the PDA, the digital course handouts in PDF and PowerPoint format with many pictures or words were considered not appropriate for PDA use. E-books from the university library were not designed for free downloads by students to their devices. WebCT could not be accessed using the PDA, and until now only a few websites have been designed for PDA use.

The *multimedia collection* affordance, though not used as frequently as *multimedia access*, was found to be most helpful for collaborative learning activities (e.g., doing lab reports by sharing the captured lab results using the Camera function), reflective learning (e.g., listening to the recorded lectures/tutorials, reviewing notes taken in some lectures), and coping with emerging events (e.g., taking pictures of some handouts, leaflets, and banners on the spot for later use). Data collection for experiential learning has also been widely reported in handheld educational application literature (e.g., Chen et al., 2003, Lai et al., 2007). This affordance will have great potential for educational use in varied contexts.

Communication was another frequently used affordance. The varied forms for communication - E-mail, SMS, MSN, and phone - afford different possibilities for educational practices. For example, communication via email using the handheld device is written, and can be either long or short; communication via SMS is limited to certain numbers of letter or words; and communication via phone calls is achieved verbally. These different forms of communication offer different potential uses for educational practices.

Among all the communication means, it seems that e-mail has great potential for learning purposes. It can help students solve problems efficiently when other means of communication are not available or inconvenient to use. Proper use of email communication has been reported helpful for supporting learning through shared information and discussion (e.g., Bossano, 2006; Clegg, MacManus, Smith, & Todd, 2006), delivering short language courses (e.g., Thornton & Houser, 2005), and enriching learning experiences (e.g., Hassini, 2006). With further development of technology, it is expected that emailing using handheld devices will play a more important role in education for immediate needs if free Internet access can be achieved anywhere, anytime.

The phone call was reported to be used most frequently by students. The penetration rate of handheld devices in Hong Kong is about 124.7 percent – one of the highest in the world based on the statistics reported in March 2006 (<http://www.info.gov.hk/info/hkbriefer/eng/living3.htm#communications>). This provides a solid basis for using voice communication via handheld devices for educational practices in Hong Kong. Though handheld devices are often considered a disruptive technology for classroom learning (e.g., Sharples et al., 2002), there have been some research studies involved in voice communication via handheld devices in class. For example, handheld devices have been used in a mobile communication system to improve the efficiency of medical practice (Hanada, Fujiki, Nakakuni, & Sullivan, 2006), and enhance interactivity in a web discussion forum (Wei, Chen, Wang, & Li, 2007). Possible uses of the handheld device as a voice communication tool, under certain controlled systems or strategic rules, can be developed in the future to deliver synchronous anytime, anywhere learning packages.

Word processing affordances can be used to supplement or take the place of desktop or laptop computers to process data such as Word files or Excel files in certain contexts. Due to the limitation of the small screen size of handheld devices, editing and processing files using handheld devices is not as efficient as when using desktop or laptop computers. However, this data processing affordance does provide opportunities for students to carry out immediate tasks when other devices are not available.

Connectivity affordances provided opportunities for students to do collaborative and constructive learning (Jonassen, 2008) by sharing files, exchanging views and comments, and constructing ideas collaboratively. However, the students pointed out that if handheld devices are not commonplace among all students, it will be hard to achieve the learning purposes. This factor has to be considered before handheld device implementation into student learning practices.

Finally, *representation* affordances can be used to represent ideas and understandings using sketches, graphics, or simply words. As a tool, a PDA creates context for supporting 'learning by doing' (Jonassen, 2008). In investigating educational affordances of PDAs based on a technical education teacher's explorative uses, Churchill and Churchill (in press) also reported that PDAs can be used as a representational tool. However, their interpretation of such tool use refers to created representations such as mind maps or captured or edited images. Nevertheless, the handheld device as a representation tool can offer many possibilities for supporting knowledge construction in learning.

Conclusion

This research study identified seven affordances of the PDA for learning explored and used by undergraduate students at a university. They are: *multimedia collection*, *multimedia access*, *communication*, *scheduling*, *data processing*, *connectivity* and *representation*. In addition, some constraints of the PDA were found in relation to small screen size, limited computational power, and poor audio quality that shaped or hindered the students' use of the PDA. Institutional and social factors also had some impact on PDA use.

We are not claiming that the affordances gleaned from this study are novel, but rather this paper demonstrates how students perceive and use the affordances of PDAs to support their academic studies in higher education. This research study is exploratory in nature due to the small number of students involved and is by no means meant for generalization to a larger population. Nevertheless, the educational affordances of the handheld device explored in this research may shed some light on what uses students prefer, how students tend to use handheld devices for their practices, what constraints of the PDAs exist, and what institutional and social factors may influence PDA use. This, in turn, may help inform researchers and teachers of how to take advantage of the affordances of the PDA in their pedagogic practices.

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